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ABSTRACT

This paper reports on an on-going action research study of the elementary school science education courses at the University of Victoria. The Department of Social and Natural Sciences requires that professors evaluate their teaching effectiveness annually using a variety of methods including student evaluations, peer observations, course outline analyses, and others approved by the department chair. This requirement provides an excellent opportunity to conduct action research to document teaching, reflect on teaching, improve practice, and revise course outlines based on multiple sources of data. The research focuses on science instruction in the elementary school and describes 1980s' programs as lacking a central, clear, philosophical, psychological, pedagogical framework. The "National Board for Professional Teaching Standards" and the "Report of the National Commissions on Teaching and America's Future" are cited which provide both generalist and science-specific frameworks on which elementary school science education and teacher education programs can be judged. (Contains 31 references.) (YDS)

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USING NEGOTIATED CRITERIA AND PEER-EVALUATION IN UNDERGRADUATE ELEMENTARY SCHOOL SCIENCE EDUCATION PROGRAMS

ED 441 693

Larry D. Yore, University of Victoria

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Introduction

This paper reports on an on-going action research study of the elementary school science education courses at the University of Victoria. The Department of Social and Natural Sciences requires that professors evaluate their teaching effectiveness annually using a variety of methods—student evaluations, peer observations, course outline analyses, and other methods approved by the department chair. This requirement provides an excellent opportunity to conduct action research to document teaching, to reflect on teaching, to improve practice, and to revise course outlines based on multiple sources of data. The negotiated criteria, peer-evaluation, and student-led workshop components of Ed-E 445A: Science Instruction in the Elementary School are the foci of this paper.

Background

Elementary science teacher education has lacked a consistent focus and direction over the last 10-15 years. A quick inspection of 1980s national and regional conferences on science teaching and science teacher education reveals a loose collection of interesting ideas and effective programs without a central, clear, philosophical, psychological, pedagogical framework. The *National Science Education Standards* (NRC, 1996) explicitly addressed this lack of clarity by including teaching, assessment, content, program, and professional development standards. The science standards, taken in conjunction with the *National Board for Professional Teaching Standards* (NBPTS, 1994) and the Report of the *National Commission on Teaching and America's Future* (NCTAF, Darling-Hammond, 1996), reaffirm the importance of

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teachers, teaching, and hands-on/minds-on learning as primary influences on student's thinking, academic achievement, emotional disposition, and science literacy and have renewed the emphasis on teaching and teacher education research. These documents provide both generalist and science-specific frameworks on which elementary school science education and teacher education programs can be judged.

Shulman (1987) encouraged designers of teacher education programs to articulate and coordinate the content knowledge, pedagogical knowledge, and content-pedagogical knowledge components of a program. Surveys of elementary teachers indicate that practicing teachers believe they lack appropriate science content knowledge. The surveys also indicate that practicing teachers do not value their preservice science education courses. These reflections indicate that science and science education components of elementary teacher education programs are not effective in that they do not address the perceived needs of classroom teachers, do not reflect reasonable expectations and current conditions of classrooms, do not provide depth of understanding, and do not convince preservice teachers of their value. In part, this situation is due to the disconnected internal relations within the university but it is also due to the disconnected nature of the program's campus-based and field-based components (Roth & Pipho, 1990; Yager & Penick, 1990).

The 1960s science education reform produced a series of false dichotomies, process/product, child-centered/subject-centered, structured/unstructured, basics/higher-order thinking, etc. Contemporary perspectives must address these false propositions—all teaching must "merge commitment to students with allegiance to knowledge at all grade levels" (NBPTS, 1994, p. 10); integrate knowledge, inquiry skills, habits-of-mind and critical thinking (NRC, 1996); and balance appropriately content structure, teacher structure and students' self-regulation to enhance learning (Yore, 1984; 1986). The NCTAF report states "students are entitled to teachers who know their subjects, understand their students and what they need, and have mastered the professional skill required to make learning come alive" (Darling-Hammond, 1996, p. 6). The report goes on to recommend that American education get serious about standards for

teachers and students, teacher education and professional development be reinvented, teacher recruitment be overhauled, teaching knowledge and skills be encouraged and rewarded, and schools be reorganized as places for teaching and learning.

General Standards for Teaching

The NBPTS (1994) described a vision of effective teaching generally that contains five core propositions and developed a national teacher certification program based on standards for these propositions (abstracted from pp. 6-8):

1. Teachers are Committed to Students and Their Learning:

   Board-certified teachers are dedicated to making knowledge accessible to "all" students. They act on the belief that "all" students can learn. They treat students equitably, recognizing individual differences and taking account of these differences in their practice. They adjust their practices as appropriate, based on observation and knowledge of their students' interests, abilities, skills, knowledge, family circumstances, peer relationships, and culture.

2. Teachers Know the Subjects they Teach and How to Teach those Subjects to Students:

   Board-certified teachers have a rich understanding of the subject(s) they teach and appreciate how knowledge in their subject is created, organized, linked to other disciplines, and applied to real-world settings. While faithfully representing the collective wisdom of our culture and upholding the value of disciplinary knowledge, they also develop the critical and analytical capacities of their students. They are aware of the preconceptions and background knowledge that students typically bring to each subject and of strategies and instructional materials that can be of assistance. They understand where difficulties are likely to arise and modify their practice accordingly.

3. Teachers are Responsible for Managing and Monitoring Student Learning:

   Board-certified teachers create, enrich, maintain, and alter instructional settings to capture and sustain the interest of their students and to make the most effective use of time. They also are adept at engaging students and adults to assist their

teaching and at enlisting their colleagues' knowledge and expertise to complement their own. Accomplished teachers command a range of generic instructional techniques, know when each is appropriate, and can implement them as needed. They know how to engage groups of students to ensure a disciplined learning environment and how to organize instruction to allow the schools' goals for students to be met. They employ multiple methods for measuring student growth and understanding and can clearly explain student performance to parents.

4. Teachers Think Systematically about their Practice and Learn from Experience:
Board-certified teachers are models of educated persons, exemplifying the virtues they seek to inspire in students—curiosity, tolerance, honesty, fairness, respect for diversity, appreciation of cultural differences—and the capacities that are prerequisites for intellectual growth: the ability to reason and take multiple perspectives, to be creative and take risks, to adopt an experimental and problem-solving orientation. Accomplished teachers draw on their knowledge of human development, subject matter and instruction and on their understanding of their students to make principled judgments about sound practice. Striving to strengthen their teaching, Board-certified teachers critically examine their practice, seek to expand their repertoire, deepen their knowledge, sharpen their judgment, and adapt their teaching to new findings, ideas, and theories.

5. Teachers are Members of Learning Communities:
Board-certified teachers contribute to the effectiveness of the school by working collaboratively with other professionals on instructional policy, curriculum development, and staff development. They can evaluate school progress and the allocation of school resources in light of their understanding of state and local educational objectives. They are knowledgeable about specialized school and community resources that can be engaged for their students' benefit and are skilled at employing such resources as needed.

Science Education Standards

The *National Science Education Standards* (NRC, 1996) apply these general assumptions about commitment to all students, effective teaching, authentic assessment, organizational abilities, reflective practice, leadership and professionalism to science teaching, science learning, and science teachers. The science standards describe the collective content-pedagogical knowledge, grade-appropriate goals, and actions needed for effective science teaching. The teaching standards address: (1) planning inquiry science programs, (2) actions required to guide and facilitate learning, (3) assessments of teaching and learning, (4) environments that promote learning, (5) communities of learners to support learning , and (6) planning and development of school-wide science programs. The assessment standards recognize the importance of how evaluation drives teaching and learning and the need to have goals, teaching, and evaluation aligned. The standards address: (1) the consistency of assessment information and educational decisions, (2) consideration of both achievement and opportunity, (3) the match between technical quality and consequences, (4) the fairness of assessment practices, and (5) the soundness of inferences modeled from assessment data. The professional development standards envision true professionalism and a seamless professional education system for science teachers that includes preservice, induction (early years of teaching), and continued professional education. The standards address: (1) learning science content through inquiry, (2) integrating content knowledge and pedagogical knowledge into learner/topic appropriate content-pedagogical knowledge, (3) lifelong learning, and (4) coherence and integration of professional development programs.

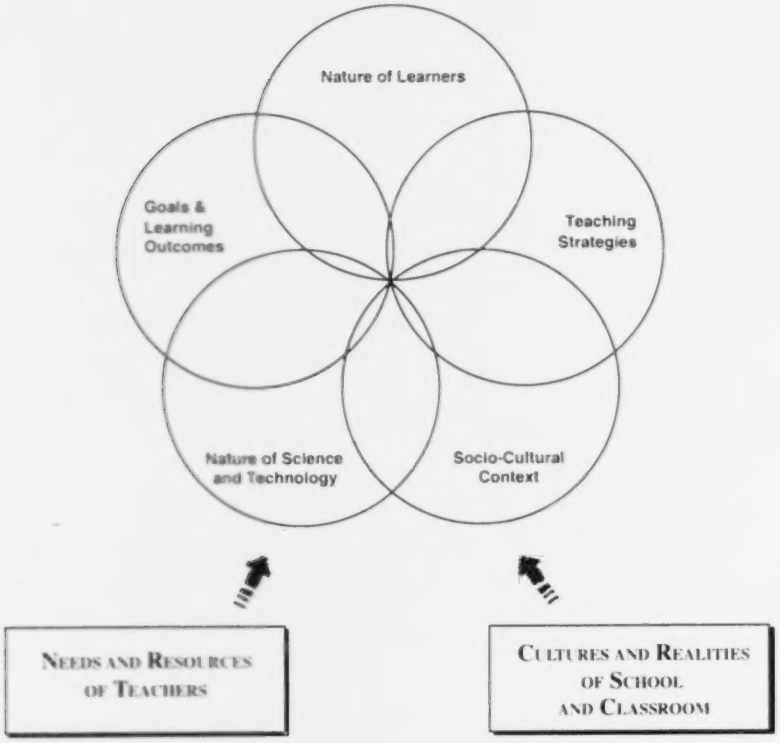
Teaching All Students Science

Teaching is a complex endeavor involving a balancing act while juggling numerous factors. "The education challenge … is not that its schools are not as good as they once were, it is that schools must help the vast majority of young people reach levels of skills and competencies once thought within the reach of a few. To help diverse learners master much more challenging content, teachers must go far beyond dispensing information, giving a test, and

giving a grade" (Darling-Hammond, 1996, p. 8). The constructivist teaching envisioned by contemporary reforms is much more demanding on teachers requiring thousands of decisions and adjustments during each lesson (reflection-in-action) and analysis of teaching effectiveness after the lesson (reflection-on-action). Teaching is too complex to understand in its totality; deconstructing teaching into separate components is dangerous, but it is necessary to explore the interacting parts to better understand the holistic process (Figure 1).

The inclusive nature of the science standards, the multicultural nature of North American schools, and the humanistic nature of school policies involving mainstreaming special needs students have placed increased importance on the nature of the learners. The composition of many elementary school classes produces a rich mosaic of cultures, languages, and belief systems that provide a challenge to science teachers and need consideration during instructional planning and teaching (Lee, 1997). Likewise, the inclusion of special needs students in most classrooms changes the delivery mode, pace, and organization of most science teaching.

Figure 1
Compatibility Model for Science Teaching and Learning


Nature of Learners
Goals & Learning Outcomes
Teaching Strategies
Nature of Science and Technology
Socio-Cultural Context
Needs and Resources of Teachers
Cultures and Realities of School and Classroom

The science teaching standards imply that science teaching should utilize a constructivist approach without specifying the exact nature of teaching strategies. Constructivism has many interpretations (faces) in education (Good, Wandersee & St. Julien, 1993; Phillips, 1995). The faces of constructivism provide a "range of accounts of the processes by which knowledge construction takes place. Some clarification of these distinct perspectives and how they may interrelate" is needed as this epistemic theory is used to construct compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). The individual faces have some common assumptions (basics) and important differences (world view, view of scientific knowledge, locus of mental activity, locus of structure/control, discourse, etc.).

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Basics of Constructivism. Accounts of the various interpretations of constructivism agree that understanding is actively made out of, invented from, or imposed on personal experiences. The construction process and the resulting constructs are influenced by the learners' prior knowledge, memory, cognitive abilities, metacognition, interpretative framework, and sociocultural context. Each interpretation encourages meaningful learning of integrated knowledge networks through active deliberation, resolution, debate, and reflection of cognitive conflicts; and each has discounted rote learning, isolated skills, and drill-practice. Furthermore, each interpretation agrees that people have misconceptions within their prior knowledge and that these misconceptions are not indications of stupidity; are found across age groupings, content areas, cultures, and national boundaries; and are resistant to change. Replacement of misconceptions with more scientifically acceptable conceptions requires that the new concept be sensible, rational, usable, and powerful.

The Different Faces of Constructivism. The constructivist theory is based on a collection of philosophical and psychological theories, models and ideas–cognitive equilibrium, zone of proximal development, semiotic interactions, capacity of working memory, etc. (Fosnot, 1996). The different faces of constructivism recognize the basic assumptions but appear to emphasize specific aspects to greater or lesser degrees. Henriques (1997) established a comparative framework for four faces of constructivist approaches: information processing, interactive-constructive, social constructivist, and radical constructivist. Yore and Shymansky (1997) analyzed these four faces and their embedded philosophical, psychological, and epistemic assumptions. Information processing utilizes a computer metaphor to illustrate learning in which a series of sub-routines or micro-processes generates ideas and analyzes errors that lead to closer and closer approximations of a knowledge network, the right answer, and causality (Fisher & Lipson, 1985; McCarthy & Raphael, 1992). The interactive-constructive model utilizes a hybrid ecological metaphor (organism, environment, machine) to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence of

Nature and privately integrated (assimilated or accommodated) into the person's knowledge network within the limited capacity of working memory and stored in long-term memory (Shymansky, Yore, Treagust, Thiele, Harrison, Stocklmayer, & Venville, 1997). Social constructivism utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are resolved by social negotiations resulting in consensus and common understanding at the group level (McCarthy & Raphael, 1992). Radical constructivism utilizes an organism metaphor to illustrate learning in which intrapersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency (Airasian & Walsh, 1997; Phillips, 1995; von Glaserfeld, 1987).

These four faces of constructivism have unique philosophical, psychological, epistemic, and pedagogical profiles (Table 1, Yore & Shymansky, 1997). World view involves ways of thinking about how the world works–mechanistic, organistic, contextualistic, and hybrid (Prawat & Floden, 1994). Mechanistic views stress the important role of antecedent events as influence on behavior. Contextualistic views stress the importance of situation and environment. The meaning of an act may undergo changes as it unfolds in a dynamic environment, and the pattern of events in a sociocultural context have low predictability. Organistic views stress the importance of the organism as a whole. Reality is only what the organism subjectively perceives; knowing is an individualistic event. Hybrid views stress the importance of interactions with the physical world (natural and people-built) as well as the sociocultural context, recognize that interpretations reflect lived experience and cultural beliefs of the knowers, but require all interpretations to be judged against evidence grounded in Nature. Epistemic view of science (Hofer & Pintrick, 1997; Kuhn, 1993) represents the structure of knowledge and ways of knowing–absolutist (a single right answer is proven), evaluatist (multiple interpretations are tested and supported or disconfirmed), and relativist (multiple interpretations are equally valid). Locus of mental activity represents the beliefs about where understanding is created–privately deep within the mind and brain of the individual (activity flows from periphery to core where irrelevant stimuli are discarded, leaving abstract representations of critical and

essential information or activity focused on subjective experiences, extracting internal coherence and where rightness is seen as the fit with personally established order); publicly within the dynamics of the group (activity is on the interface between the individual and the environment where the collective wisdom of the group and craft knowledge of the community construct understanding); and publicly and privately in which possibilities are surfaced, clarified, and narrowed by group negotiations but actual meaning is made privately by individuals reflecting on these possibilities (Hennessey, 1994; Prawat & Floden, 1994). Locus of structure/control represents an epistemic influence, a pedagogical feature and the pragmatics of classroom teaching dealing with who sets the agenda for study within a specific discipline–teachers, students, or shared. The nature of the science discipline being studied (physical sciences, biological sciences, earth-space sciences) centered contributes to the contextual structure of inquiry-oriented lessons (Yore, 1984, 1986). The content structure complements the teacher structure and the students' self-direction. Discourse represents the combined psychological-pedagogical feature of type and purpose of interpersonal and intrapersonal communications in the classroom–one-way communications of expert to novice, one-way communications of person to self (inner speech the language tool of thinking and spontaneous conception) and two-way communications among people to negotiate clarity or consensus (Fosnot, 1996; Prawat & Floden, 1994).

Science Assessment

The science assessment standards identify "essential characteristics of exemplary assessment practices, the standards serve as guides for developing assessment tasks, practices, and policies, ... (and they) can be applied equally to the assessment of students, teachers, and programs; to summative and formative assessment practices; and to classroom assessments as well as large-scale, external assessments" (NRC, 1996, p. 75). Contemporary interpretations of assessment recognize that assessment drives teaching and learning and that learning outcomes, teaching strategies, and assessment techniques must be aligned. Shymansky (1994) suggested that contemporary assessment has moved toward informing instruction and empowering learning

and away from simply grouping and ranking students based on isolated fragments. Constructivist teachers focus on finding out what (a) students already know and utilize this information to plan instruction and to teach, (b) how students learn something, and (c) how they feel about their learning. Ultimately, assessment should move from control by the teacher, to shared control of teacher and student, to the executive control of the student (self-regulated learning).

Table 1

Philosophical, Psychological, Epistemic and Pedagogical Features of Information Processing, Interactive-Constructivist, Social Constructivist and Radical Constructivist Approaches (Yore & Shymansky, 1997)

Feature	Information Processing	Interactive-Constructivist	Social Constructivist	Radical Constructivist
World View	Mechanistic	Hybrid	Contextualistic	Organistic
Epistemic View of Science	Absolutist (Traditional) Nature as Judge	Evaluative (Modern) Nature as Judge	Evaluative (Postmodern) Social Agreement as Judge	Relativist (Postmodern) Self as Judge
Locus of Mental Activity	Private	Public and Private	Public	Private
Locus of Structure/Control	Teacher	Shared: Teacher and Individuals	Group	Individual
Discourse	One-Way: Teacher to Student	Two-Way: Negotiations to Surface Alternatives and	Two-Way: Negotiations Leading to Consensus	One-Way: Individual to Self (Inner Speech)

The underlying assumptions of constructivist-oriented assessment is to collect accurate, consistent information of authentic learning in a realistic context that closely parallels and is embedded in the instruction (Yore, Williams, Shymansky, Chidsey, Henriques, & Craig, 1995). Furthermore, the assessment needs to reflect the intended use and the risk involved. Assessment needs to move away from behavioral–based, fragmented objective testing toward more authentic, holistic performance and depth of understanding approaches. Several approaches have promise: two-part objective items, confidence weighting, concept mapping, observational checklists, interviews, and performance tasks. Each approach requires clearly articulated targets and sound scoring rubrics (Luft, 1997; Nott, Peave & Reeve, 1992).

Practicing teachers report that negotiating clarity of the desired outcome and establishing scoring procedures are among the most meaningful professional development activity available. This mediation process involves groups of informed teachers that clarify the desired performance and establish mutually exclusive, exhaustive, and ordered categories of performance. The scoring rubric can describe a holistic performance or establish analytical components believed to comprise the performance. The ordered set of categories within either of these rubrics represents increased quantity of performance and qualitative shifts in performance. Frequently, more of the same type of performances are inter-mixed with the onset of new types of performance.

Negotiating criteria has been used with students to clarify language arts tasks and to establish metacognitive awareness of tasks (Anthony, Johnson, Heckelson & Preece, 1991). Repeated use of negotiated criteria with novices helps the students more completely understand the standards expected of expert performance and puts the novices in a position to monitor and regulate their performance. They claim that negotiated criteria establishes ownership, improves performance, and increases students' satisfaction with their evaluations.

Professional Development.

The standards for professional development describe a seamless experience leading preservice teachers into an induction year and to certified status. Clearly this vision requires elementary school science education programs that provide authentic problem-centered learning experiences and that produce elementary science teachers within the teaching profession willing to assume the roles of change agent, mentor, and model. Many good innovations and educational changes are not fully implemented because leadership is not provided at the target level (classrooms, teachers, students) or transferred from the innovators to the grassroots change agents. Leadership must be a central goal of science education programs; therefore, leadership training needs to be a part of undergraduate coursework. Leadership envisioned here is illustrated by teachers taking on responsibility for curriculum committees, ordering equipment, providing mentorships for new teachers, active membership in science teacher organizations, writing professional articles, giving conference presentations, and conducting professional development workshops.

Cascading leadership addresses the traditional distinctions between advocates, sponsors, change agents, and targets. "The challenge of professional development for teachers of science is to create optional collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers" (NRC, 1996, p. 58). Furthermore, local resource people are needed to support teachers' continued professional growth when external expertise is used to initiate inservice. Frequently these resource people are among the most recent teachers to join the school staff (Henriques, 1997). Providing teachers with opportunities to conduct workshops allows them to not only share and demonstrate their expertise but also opportunities to reflect, compare, contrast, and revise their exemplary practice (NRC, 1996).

The University of Victoria's Elementary School Teacher Education Program

The University of Victoria is authorized by the British Columbia College of Teachers to offer elementary education programs that meet its standards. The regular program leads to a

B.Ed. degree in five years. Most students enter after either one or two years of general-liberal academic courses in the Faculty of Arts and Sciences of a college or university. The third year is a pre-professional year with content, general pedagogical and limited methods (physical education, music, drama, and art) coursework, and a two-week clinical experience at the end of the year. The fourth year is the professional year with further foundations and methods courses and two six-week practica, which leads to certification. The fifth year may be done after teaching has begun and is designed to give teachers a concentration in a specific curricular area of their interest. Currently, most students stay onto complete the fifth year, since it provides a higher salary and teaching positions are presently in short supply.

Science Education

The science education component of the elementary teacher education program at the time of this study (1996-97) ranges from the basic core to two levels of specialization: a concentration and a teaching area (Figure 2).

Laboratory Science Requirements

The core science education requirements are 3 to 4.5 units (1.5 units = 3 semester hours or 4.5 quarter hours) of laboratory science and 2 units of science methods. The most popular electives to fulfill the laboratory science requirements are SNSC 145A, SNSC 145B, and SNSC 145C. These content courses were designed by the Department of Social and Natural Sciences to provide a non-calculus, conceptual, hands-on/minds-on orientation to understanding physical science, earth-space science, and biological science concepts. These courses focus on specific content knowledge embedded in the provincial elementary school science curriculum (K-7) and the professors attempt to demonstrate the desired constructivist pedagogical strategies in their teaching but do not explicitly stress the pedagogical aspect.

Science Methods

The required elementary school science methods course (ED-E 745) meets 50-54 hours during 19 weeks spread over two semesters or concentrated during six weeks depending on the specific program. Student teaching experiences (practica) are embedded in the last six weeks

(November-December) of the first semester and in the final six weeks (April-May) of the second semester during the regular program or the science methods course is embedded midway (November-December) during a year-long internship program. The philosophy of science

Figure 2
Science Education Component of the Elementary B.Ed. Program

ELEMENTARY SCIENCE EDUCATION PROGRAMS
University of Victoria

	Core	Concentration	Teaching Area
Year 1/2	* 3 - 4.5 units University Lab Science	* 3 - 4.5 units University Lab Science	* 3 - 4.5 units University Lab Science
	* If Grade 11/12 Science, requirement reduced. Most frequent courses SNSC 145A (1.5) - Physical Science, SNSC 145B (1.5) - Earth Science, SNSC 145C (1.5) - Biological Science		
Year 3	None	**SNSC 345B (1.5)** Science-Technology- Society Issues in Science Education	**SNSC 345B (1.5)** Science-Technology- Society Issues in Science Education
		SNSC 373 (1.5) Environmental Education	**SNSC 373 (1.5)** Environmental Education
		SNSC 345A (1.5) Selected Topics in General Science	**SNSC 345A (1.5)** Selected Topics in General Science
Year 4	**ED-E 745 (2)** Curriculum & Instruction in Elementary Science	**ED-E 745 (2)** Curriculum & Instruction in Elementary Science	**ED-E 745 (2)** Curriculum & Instruction in Elementary Science
Year 5	None	**ED-E 438A (1.5)** Computer Applications in the Instruction of Elementary Math, Science and Social Studies	**ED-E 438A (1.5)** Computer Applications in the Instruction of Elementary Math, Science and Social Studies
		ED-E 445A (1.5) Science Instruction in the Elementary School	**ED-E 445A (1.5)** Science Instruction in the Elementary School
		ED-E 445B (1.5) Contemporary Issues in Elementary Science Curriculum	**ED-E 445B (1.5)** Contemporary Issues in Elementary Science Curriculum
		ED-E 473 (1.5) Environmental Issues in Education	**ED-E 473 (1.5)** Environmental Issues in Education

	Core = 5 - 6.5 units	Other Sciences	Other Sciences
TOTAL		Core + 9 units	Core + 15 units

1.5 units equals 3 semester hours or 4.5 quarter hours

education methods is heavily influenced by the contemporary science education reforms and applied cognitive science, and curriculum and instruction are linked to an interactive-constructive perspective of teaching and learning (Shymansky, et al., 1997). ED-E 745 attempts to develop content-pedagogical knowledge and teaching strategies regarding the philosophical and psychological foundation of the science curriculum and instruction, the goals of the curriculum, inquiry skills, and authentic assessment. Contemporary articles from professional journals (*BC Catalyst, Science Scope, Science and Children*, etc.) and provincial curriculum documents (*Integrated Resource Package: Science K-7*, etc.) are used to elaborate classroom activities and discourse. Most often the educational idea under consideration is used to demonstrate the idea itself. Therefore, activities from the provincially recommended curriculum materials that are interesting and challenging to adult learners are used to illustrate the attributes of the inquiry-oriented curriculum; and instructional strategies are modeled prior to being discussed. Considerable planning takes place to ensure that students have had concrete experience with an idea before the idea is formally discussed and potential classroom applications and associated teaching strategies are described. The practica provide authentic context to apply these ideas.

Science Education Specialization

The "concentration" in science requires a further 9 units (6 courses) of science content and science content-pedagogical courses over and above the core requirements. The "teaching area" in science requires a further 15 units (10 courses) of science content and science content-pedagogical courses over and above the core requirements. Students may elect from a variety of content courses in Earth and Ocean Sciences, Environmental Studies, Chemistry, Physics, Biology, and Biochemistry. Students must complete upper-level STS, technology applications, advanced instruction, and advanced curriculum courses.

The Action Research Focus

Course Content

ED-E 445A: Science Instruction in the Elementary Schools is a 1.5 unit course focused on advanced science instruction (teaching and assessment) in kindergarten to grade 7. The course meets 3 hours per week during spring term and normally serves as the keystone course in the science concentration and teaching area for 10-15 students per year. ED-E 445A is designed to provide science education students with:

1. awareness of provincial, national and international trends in science education and science literacy.

2. knowledge and sensitivity to factors influencing the selection of instructional strategies, i.e., nature of science, nature of learner, desired outcomes, available resources, classroom and school environments, others.

3. knowledge about and skills related to specific instructional strategies.

4. ability to select, develop, implement and justify the use of specific instructional strategies.

5. leadership skills related to improving science instruction.

The seminar nature of the course allows the professor to personalize the course and to utilize a variety of human and instructional resources. Recently the *National Science Education Standards* (NRC, 1996), reprints from *Science and Children, Science Scope* and other professional journals, and reference articles and textbooks (placed on reserve in the Curriculum Library) have served as the print supplements for the course. The following topic outline and assignments were used in 1997:

Topics

I The Private Universe and *Times-Colonist* Article on Adult Science Literacy
Making a Difference as a Science Teacher

Nature of Science, Technology and Social Studies; Science Literacy; and Multiculturalism

II Science Education in North America and B.C.
- a. NSTA Scope, Sequence and Coordination
- b. AAAS Science for All Americans and Benchmarks for Science Literacy
- c. NRC Standards (pp. 1 - 26)
- d. BC Science Integrated Resource Package for Science (K-7)
- e. Pan Canadian Framework for Science (1996 Working Draft)

III The Many Faces of Constructivist Teaching/Learning (NRC, 1996, pp. 27 - 54)
- a. Information Processing
- b. Teacher-Guided Inquiry
- c. Conceptual Change
- d. Interactive-Constructive
- e. Social Constructivist
- f. Radical Constructivist

IV Assessment Alternatives (NRC, 1996, pp. 75 - 103)
- a. Performance Tasks and Scoring Rubrics
- b. Concept Mapping and Scoring Procedures
- c. Think Alouds
- d. Negotiated Criteria

V Content Standards (NRC, 1996, pp. 103 - 172)
- a. K - 4 Content Standards
- b. 5 - 8 Content Standards
- c. Analysis of B.C. Science Integrated Resource Package for Science (K - 7)
- d. Exploring New Curriculum Resources (FOSS, AIMS, STC, Insights)

VI Basic Inquiry Teaching and Learning Approaches
- a. Generative Approach
- b. Learning Cycle
- c. Conceptual Change
- d. Promoting Social Discourse
- e. 4-part Teaching Strategy

VII Science Instruction Utilizing Alternative Approaches (Student-Presented Workshops)

a. Guided Imagery
b. Role Playing
c. Games
d. Simulations
e. Models, Analogues and Metaphors
f. Peer Teaching and Learning
g. Cooperative Learning
h. Structured Controversy
i. Case Studies
j. InterNet
k. Computer Assisted, Microcomputer-Based Laboratory, etc.
l. Projects
m. Science Camps: Science Venture, CRD Parks, Swan Lake
n. Science Fairs
o. Problem Solving: Science Odyssey, Invention Conventions, Science Olympics
p. Others

VIII Reading-to-Learn: Explicit Content Reading Instruction in Science
a. General Plans
b. Teaching Sequence: Do First, Read Later
c. Strategy Development Embedded in Authentic Inquiry

IX Writing-to-Learn: Content Writing Activities in Science

Assignments

1. Term Paper

A ten-page position paper on an assigned topic. The paper will include 10-15 references. Your expert-group composed of students with the same topic will share ideas and resources, while the other expert-groups will provide reactions and editorial feedback on drafts #1 and #2 of your paper. The instructor will grade draft #3. A draft #4 will be allowed for those students wishing to improve their grade.

Topics:

A. Nature of science, social studies, mathematics and technology. How should they influence what we teach and how we teach Elementary School science.
B. Multi-culturalism. How should it influence what we teach and how we teach Elementary School science.

C. Cross-curricular aspects of literacy and a conceptual framework for science literacy. (30 points)

2. Class Presentation
A 30-minute workshop on an instructional strategy (see topic VII). A substantive class hand-out that provides description, research support and application of the strategy is required. (20 points)

3. Teaching Internship in Science
A three-week science teaching project at an elementary school (TBA). Two students will work with a classroom teacher to identify, develop and deliver a science unit consisting of 6-10 hours of instruction and evaluation. (30 points)

4. Examination
Two (2) hour comprehensive examinations. A pool of questions will be provided in advance and the examination will be selected from these questions. (20 points)

Assessment and Workshop Components

ED-E 445A attempts to develop science education in five ways: knowledge about science education reforms, curricula, instruction, and assessment; communication skills (oral and written); workshop experience; collaborative planning; and reflective practice. The specific foci of this action research were the assessment and workshop activities.

Students in this course hold or could hold a Standard Teaching Certificate (Level 4) since they have successfully completed their student teaching and four years of post-secondary education. In fact, many of the students are serving as teacher-on-call (TOC) in local school districts while completing their year five course work. This means that they are well informed about science education in local schools and are somewhat more self-confident, futuristic and risk-takers than most preservice students. They realize that not everything addressed in the course will be usable the next day and that some of the benefits of the course will be realized as they become practicing teachers.

With such students several activities are possible that may not be appropriate with other students—collaborative essay writing negotiated criteria for and peer-evaluation of student-led

workshops and science teaching internships. The collaborative writing, task has enhanced the students' writing ability and their willingness to publicize their ideas (Yore, 1996). The internship was developed as a platform to enhance preservice teachers' science teaching experience and to promote school science leadership (Yore, 1997).

The focus of this study was the use of negotiating criteria for an elementary school science workshop and the use of these criteria in the peer-evaluation of a student-led workshop. The eleven students in this course had experienced professional development workshops during their university courses and student teaching experiences. They had reasonably well-articulated expectations of effective and ineffective workshops.

The professional development standards were used to provide a rationale for the workshop assignment, and the changing emphasis in professional development was used to crystalize the discussion (NRC, 1996, p. 72). Small groups of 3 or 4 students were asked to develop a list of attributes of an effective elementary school science workshop and to develop a rationale for why the attributes were important. Large- group discussion integrated the small-group results with the NRC standards to provide greater clarity and a local context. During these negotiations three general dimensions were identified for effective workshops:

1. Practical ideas based in exemplary practice, current curriculum, and contemporary theory: experiences, illustrations, and examples.
2. The presentation should demonstrate effective teaching practice and should help participants enhance their practice: multimedia, constructivist, concrete hands-on/minds-on, and focused.
3. Handouts should provide participants with a permanent record of the experience, reinforcement and enrichment of their understanding, and link the workshop to other resources: print copy of ideas, explicit connections to theory, references to science journals, and instructional resources.

Further discussion of these dimensions indicated that they were not all of equal importance. The group decided to weight the scoring procedures to more accurately reflect each dimension's

importance. The decision was made to assign 40% of the total score to the first dimension and 30% of the total score to each of the second and third dimensions and that the holistic rating would be the composite of the three dimensions scores.

A draft rating chart was developed by the professor based on the group decision and submitted to the class at the next meeting for their approval. At this meeting a few minor changes were made to clarify the three dimensions. It was decided to adjust the grading procedure to anticipate that not all students would rate each student-led workshop since some students might be absent and it would be unreasonable to expect students presenting a workshop on a given day to rate other workshops given that day. The class decided to base the course grade on the average composite rating of five randomly selected peer-evaluations and the professor's evaluation. With the established criteria the student-led workshops were prepared over the next three weeks. The eleven workshops addressed a variety of science teaching ideas:

- Science beyond the classroom
- Cooperative learning approaches
- Peer teaching
- Case studies
- World wide web
- Guided imagery
- Problem solving
- Role plays
- Science fairs
- Analogues, metaphors and models
- Mad Science ® Canadian company

Not every topic was equally easy to explore in a 30-minute workshop. Therefore, a variety of workshops was presented.

Results

The effectiveness of the negotiated criteria and peer-evaluation of the student-led workshop was documented with instructional artifacts produced by the students (class hand-outs), professor's journal notes, observations, peer-evaluations, professor's evaluations, and students' course evaluation comments. Qualitative (constant comparison) and quantitative (descriptive statistics, correlations, and T-tests) analyses of these data sources were used to explore the students-professor inter-rater reliability and assertions regarding the value and improvement of the activities.

Seven to nine students and the professor rated each student-led workshop on the three dimensions negotiated earlier (Table 2). A composite rating was determined by summation of the analytical dimensions. The 92 peer-evaluations were compared with the professor's evaluations to establish inter-rater agreement and reliability. Agreement of ± 0.5 for the analytical dimension ratings was achieved for 60% of the ratings in the first dimension, 53% of the ratings in the second dimension, and 70% of the ratings in the third dimension. Only 55% of the composite ratings were within ± 1.0 agreement. When the comparison was limited to the 7 to 9 peer-evaluations and the professor's evaluations for an individual student-led workshop, the ± 0.5 agreement ranged between 29% to 100% of the ratings in specific dimensions and 29% to 78% agreement (± 1.0) for the composite rating. Greatest agreement was found for demonstrating effective practice and enhancing participants' practice (dimension 2), closely followed by agreement on the quality of the print resources provided (dimension 3). The least agreement was found for the composite ratings. Complete agreement of all dimensions and the composite was reached on 4 workshops, 75% agreement was reached on 2 workshops, and 50% agreement was reached on 5 workshops. Inspection of these groups of workshops revealed no common characteristics in quality since the composite ratings appeared to be distributed across the range of values.

Table 2

Average, Range, and Number of Peer Ratings and Professor Ratings of

Student-Led Workshops

Student ID Number		Dimension 1	Dimension 2	Dimension 3	Composite
001	Peers	7.4, 6.5-8.0 (9)	5.5, 5.0-6.0 (9)	5.7, 5.0-6.0 (9)	18.7, 16.5-20.0 (9)
	Professor	7.5	5.0	5.0	17.5
002	Peers	7.2, 6.5-8.0 (9)	5.1, 4.0-6.0 (9)	5.7, 5.0-6.0 (9)	17.9, 16.4-20.0 (9)
	Professor	7.0	4.8	5.0	16.8
003	Peers	7.1, 6.0-8.0 (7)	5.3, 4.0-6.0 (7)	5.7, 5.0-6.0 (7)	18.1, 16.0-20.0 (7)
	Professor	6.0	4.8	5.5	16.3
004	Peers	6.6, 5.0-7.5 (9)	4.9, 4.0-6.0 (9)	5.1, 5-6.0 (9)	16.6, 13.5-20.0 (9)
	Professors	5.5	5.0	5.0	15.5
005	Peers	7.0, 6.0-8.0 (8)	5.2, 4.7-6.0 (8)	5.0, 4.5-5.5 (8)	17.2, 16.0-19.0 (8)
	Professor	6.5	5.0	4.8	16.3
006	Peers	6.5, 6.0-7.5 (8)	5.1, 5.0-5.5 (8)	5.1, 4.5-6.0 (8)	16.8, 16.0-19.0 (8)
	Professor	5.5	5.5	4.8	15.8
007	Peers	7.2, 6.5-8.0 (8)	5.3, 5.0-6.0 (8)	5.7, 5.0-6.0 (8)	18.1, 17.0-19.5 (8)
	Professor	7.0	5.0	5.5	17.5
008	Peers	6.8, 6.0-7.5 (8)	5.1, 4.0-6.5 (8)	5.2, 4.5-6.0 (8)	17.0, 15.0-19.5 (8)
	Professor	6.0	4.8	4.8	15.6
009	Peers	6.8, 5.5-7.0 (9)	5.3, 4.5-6.0 (9)	5.0, 4.5-6.0 (9)	17.0, 15.5-20.0 (9)
	Professor	6.5	5.0	5.0	16.5
010	Peers	5.6, 4.0-6.0 (8)	4.4, 4.0-5.0 (8)	4.8, 4.0-6.0 (8)	14.8, 13.0-17.0 (8)
	Professor	6.0	4.8	4.8	15.6
011	Peers	7.3, 6.5-8.0 (9)	5.3, 4.0-6.0 (9)	5.5, 5.0-6.0 (9)	18.1, 16.0-20.0 (9)
	Professor	7.0	5.0	5.0	17.0

Individual students' ratings were generally higher than the professor's rating (57% for the first dimension, 48% for the second dimension, 59% for the third dimension, and 70% for the composite). About a quarter of peer evaluations exactly matched the professor's rating for the analytical dimensions (25%, 23%, 24%) while only 3% of the composite ratings matched exactly. Between 17% and 29% of the students' ratings were lower than the professor's rating. Analyses of the average ratings for the analytical dimensions and the composite and the professor's ratings indicated ± 0.5 agreement for 64% of the ratings in the first dimension, 91% of the ratings in the second dimension, and 82% of the ratings in the third dimension, while only 36% of the composite ratings agreed within ± 1.0.

Correlations of the students' ratings and professor's ratings across all workshops for specific dimensions and composite ratings revealed significant ($p \leq 0.05$) correlation coefficiencies for two analytical dimensions (dimension 1 = 0.42, dimension 3 = 0.44) and the composite (0.49). T-tests of the differences between peer-evaluations and professor's evaluations for the 11 workshops revealed that 4 differences for dimension 1 were significant ($p \leq 0.05$), 3 differences for dimension 2 and 3 were significant, and 5 differences for the composite were significant. These results indicate that a substantial majority of the peer-evaluations were similar to the professor's evaluations.

Qualitative comments were provided by the students after the completion of the course according to departmental procedures. These qualitative data were examined to identify general patterns for the negotiated criteria, student-led workshop, and peer-evaluation components of the course. The following assertions were revealed from the student comments.

Negotiated criteria for the student-led workshop as learning experience was worthwhile and practical.

- *Worthwhile and a good example of how you can include students in their own evaluation. Let us know what was expected in workshop.*

- *I thought this was an excellent idea. We all knew what was expected and how each part of the workshop was weighted markwise.*
- *Good—made it very clear to us what was expected since we created the criteria.*
- *Good idea. Criteria were clear and reasonable.*
- *The negotiated criteria worked well—I knew what I had to do and how to mark.*
- *Good to be precise on what will be evaluated.*

Suggested changes to the negotiated criteria experience: Reinforce accountability and consider diversity of workshop topics.

- *Good experience—needs accountability on the part of peer evaluation to be built in somehow.*
- *Good idea, however, keep in mind that different topics lend themselves to different criteria, i.e. not all topics can be multi-media or hands-on.*
- *It would be helpful to revisit these after the workshops because some sounded good when we talked about them in the abstract but they did not translate as easily to the real thing.*

Workshop as learning experience was useful.

- *Very useful, lots of good ideas for teaching science in a nontraditional method.*
- *Very useful. I would refine the product if I was to give the workshop again.*
- *Useful experience in setting up and delivering the information.*
- *Great learning experience. Continue (it as an assignment).*

Workshop as leadership experience improved self-confidence and presentation skills.

- *Very useful. I definitely feel capable of putting on a workshop for my peers.*
- *I enjoyed running a workshop for my peers. It added to my teaching experience.*

Suggested changes to the workshop assignment: Broaden range of topics and more time for workshop.

- *Excellent, more input as to what workshop would be about. I would have liked to have chosen my own topic.*
- *Useful, but some topics were things I had seen many times before. Perhaps a broader range of topics and push for things less familiar.*
- *It is always useful to be a part of peer workshops. I would have liked these to start earlier and maybe have only 1 or 2 each day. Otherwise, it can be overwhelming.*
- *I think this worked well. More time to present the workshop would deepen the knowledge gained but it was a good 'taste.'*

Reflections

The results of this study must be considered in the context of the size and attributes of the students involved and the unique characteristics of the course and program explored. The 11 students were highly motivated, above average ability, mature, experienced, and self-directed. There was little variation in their performance and academic achievement (B+ to A). The seminar nature of this year 5 course allowed a great deal of input from students with rich and diverse backgrounds and allowed the professor flexibility to respond to their input. The specialized nature of the program provided a common focus for the students—a desire to be an elementary school science teacher.

The overall reaction to the results were positive in that reasonably valid and reliable evaluation data were produced within a generally effective learning experience. Clearly these activities addressed many of the science teaching, assessment, and professional development standards (NBPTS, 1994; NRC, 1996). I am satisfied that these experiences provided authentic learning experiences for these preservice teachers and that these experiences were reasonable models of contemporary assessment and professional development. Negotiating criteria for the workshop illustrated how an interactive-constructive teacher can utilize student ideas in a shared-

control context. Students' ideas were explicitly valued and their ideas made an explicit difference in the grades awarded for the student-led workshop. I believe the addition of the negotiated criteria and peer-evaluation have made this course a more accurate example of the science teaching described in the *National Standards of Science Education* (NRC, 1996).

It was not surprising that peer-evaluations were higher than the professor's evaluations due to the raters' vested interests and their compassion for their fellow students. I had anticipated the deviations would be distributed somewhat more evenly above and below my ratings and that the deviations would cancel one another in the average rating. The mechanism to use the average of 5 peer-evaluations selected randomly from those submitted for each student-led workshop and the professor's evaluation to calculate the composite rating for grading purposes was fortunate. Limiting the number of peer-evaluations maximized the weighting given the professor's rating (1 of 6 rather than 1 of 8, 1 of 9 or 1 of 10) and thereby controlled the magnitude of the deviation between the averages and the professor's ratings. This procedure resulted in much higher agreement than using all the peer-evaluations to calculate the assignment grade.

Only one student expressed concern about the composite score for the student-led workshop assignment. One out-lying set of ratings selected appeared to indicate a less than complete evaluation by the peer. The appeal was considered, and a new random set of 5 peer-ratings was selected to calculate this student's grade. The procedure eliminated the out-lying set of ratings but only minimally increased the composite score. This result addressed the student's concern without totally disregarding the negotiated procedures.

The benefits of using negotiated criteria and peer-evaluation out-weighed the disadvantages. The use of constraints to minimize the deviations and the limitation of peer-evaluation to a single assignment placed the professor in reasonable compliance with the university's grading policy. The full benefits of negotiated criteria were not achieved in this limited use. In the future, peer-evaluation could be increased to include one more assignment—the collaborative writing assignment.

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